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OVERLAY DEVICE AND COMPUTER TOMOGRAPHY DEVICE COMPRISING AN EMITTER SIDE OVERLAY DEVICE

The invention concerns a gating device to delimit an x-ray beam, with at least one absorber element via which at least one slit for passage of the x-ray beam can be delimited. The invention moreover concerns a computer tomography apparatus with an x-ray radiator rotatable around a system axis, with an x-ray detector and with a radiator-side gating device.

In an examination of an examination subject or a patient in an x-ray diagnostic apparatus, the examination subject is inserted into an x-ray beam emitted by an x-ray source, and the radiation attenuation resulting from this is detected by an x-ray detector. The examination subject is thus located in the beam path between the x-ray receiver and the x-ray detector. The typical x-ray tubes used as x-ray radiators radiate x-ray radiation in a significantly larger solid angle than is necessary for examination at the patient. In order to prevent an unnecessary radiation exposure at the patient, the necessity thus exists to gate out unnecessary x-rays. For this, in conventional x-ray apparatuses it is known to apply a radiator-side gating device immediately after the x-ray radiator in the beam path, which gating device is also designated as a primary beam diaphragm. For example, such a primary beam diaphragm, with diaphragm plates which can be moved opposite to one another as absorber elements, is known from EP 0 187 245 A1.

In computer tomography apparatuses with multi-row x-ray detectors, a detector-side beam diaphragm (or a beam diaphragm near to the detector) that is mounted in the beam path between the patient and the x-ray detector is also frequently used in addition to a radiator-side gating device that is arranged in the beam path between the x-ray radiator and the patient. It is thereby possible to shade one or more detector rows of the plurality of detector rows present and to use the remaining detector rows as active detector rows. Since, in a computer tomography apparatus (in particular in such a computer tomography apparatus of the third generation), the

x-ray detector rotates around the patient together with the x-ray radiator mounted on a gantry (rotating frame), the control and/or regulation device is normally curved in the azimuthal direction. In adaptation to this geometry, in particular in order to realize a constant separation, a detector-side diaphragm disclosed in DE 42 26 861 C2 for a computer tomography apparatus is fashioned with arc-shaped diaphragm plates.

With regard to the radiator-side diaphragm, the objective exists that this only passes such rays which can also actually be detected by the x-ray detector (and in particular by its active detector rows). Other x-rays would only unnecessarily penetrate the patient and unnecessarily increase the radiation exposure. Since the multi-row x-ray detector arrays in computer tomographs are normally equipped with orthogonal rows and columns of detector elements, with regard to the primary beam diaphragm the objective exists to gate an exactly rectangular ray beam. In other words: the resulting slice profile should assume the desired shape and half-width value. Given conventional flat or planar diaphragm plates or absorber elements, this is not perfectly possible due to different separations of the x-rays of the ray beam, respectively measured from the focus of the x-ray radiator to the point of impact on the diaphragm plate. To prevent corresponding disadvantageous edge effects in the gating, in US 6,396,902 B2 an x-ray collimator is specified in which a plurality of slits of different but respectively constant width are introduced in a carrier or base body, whereby the carrier body is curved such that the gating slits are also curved. Via the curvature of the slits, it should be ensured that a ray beam (dose profile) exactly rectangular in cross section is gated on the x-ray detector.

For different examination methods, in order to be able to operate with different numbers of active detector rows or with an x-ray beam gated at different widths in the direction of the patient axis, given the x-ray collimator known from US 6,396,902 B2 the entire bearing body [hull] produced from x-ray-absorbing material must be moved. According to the local [sic] disclosure, this occurs via

rotation of the bearing body, which is why the bearing body is also curved around a second axis (shell-shape). In order to thereby also be able to bring another diaphragm slit into the matching position, the rotation axis would have to be located at the height of the focus of the x-ray radiator. This at best possible with very large mechanical effort.

Alternatively, the rotated bearing body would have to be readjusted into the correct position via a shifting movement, which is likewise very elaborate.

Moreover, the production of a bearing body curved around two axes is likewise connected with large expenditure, whereby this must also still be produced from x-ray-absorbing material, meaning from a material with a high atomic number. Moreover, what is disadvantageous from the x-ray collimator known from US 6,396,902 B2 is its large structural volume.

The invention is based on the object to specify a gating device which can be produced with less expenditure, which exhibits a small space requirement and which nevertheless allows a gating adapted to the geometry of an, if applicable, associated x-ray detector. A computer tomography apparatus should also be specified for this purpose.

The first-cited object is achieved with regard to the gating device cited above according to the invention, in that the absorber element is shaped such that the slit exhibits a slit width varying in the slit longitudinal direction.

The inventive gating device has the advantage that the absorber element or the absorber elements does not or do not necessarily have to exhibit a curved (for example banana-like) shape in order to, for example, achieve a rectangular gating. Rather, the slit can lie in one plane and likewise does not have to be curved towards a third dimension. The absorber element or the absorber elements are thus

preferably flat or essentially flat, for example disc- or rod-shaped. The gating device can thus be produced simply and with a savigs [sic] of space.

According to a preferred embodiment, considered in the slit longitudinal direction, in particular starting from a middle position, the slit width increases towards one slit end or towards both slit ends. A gating adapted to a rectangular detector geometry can therewith be particularly well achieved.

The absorber element preferably exhibits at the slit side a curved outer contour or an outer contour polygonally approximating a curvature. For example, the absorber element or the absorber elements is or are convexly-shaped at the slit side.

In an embodiment of the gating device that is particularly simple to produce, the absorber element is shaped such that the slit comprises a first region of constant slit width and at least one further region with slit width varying in the slit longitudinal direction.

Considered in the slit longitudinal direction, in particular the first region is thereby centrally arranged, and a further region with slit width varying in the slit longitudinal direction is respectively present on both sides of the central region.

According to a first preferred variant, at least one further absorber element is present in the gating device according to the invention in addition to the absorber element already cited. The further absorber element can likewise be shaped such that the slit exhibits a slit width varying in the slit longitudinal direction. The further absorber element is in particular shaped in the same manner as the already-cited absorber element, such that both look externally alike. Overall, in this variant at least opposite absorber elements are thus present. The absorber elements can be adjusted relative to one another with regard to their separation, such that the x-ray beam can be variably delimited.

In the case of same-shape absorber elements, these preferably lie mirror-symmetrically opposite one another, such that sections of the absorber elements matching one another lie opposite one another with the same slit width variation ("same slit width") with regard to an identical reference point.

The gating device according to the first preferred variant can be particularly simply produced in an advantageous manner from individually manufacturable (if applicable identical or similar) absorber elements.

In the first preferred variant, an adjustment device is preferably present that acts on the absorber elements such that the absorber elements can move perpendicular or at an angle to the slit longitudinal direction. From this, the special advantage results that the slit width is continuously or freely selectable between the curved absorber elements or diaphragm jaws [cheeks], and thus the slice thickness adjustable at a computer tomography apparatus equipped with the gating device can also assume non-discrete values. Wide detector rows can also be only partially irradiated, and thus slices that are thinner than the width of the detector elements are also possible in a simple manner.

Moreover, a readjustment of the gating device is still also possible given a modification of the focus size occurring during the operation.

The movement in particular occurs in a direction parallel to the system axis of a CT apparatus equipped with the gating device. However, a very space-saving parallelogram-like movement of the absorber elements is also possible in which, in addition to the movement component perpendicular to the slit longitudinal direction, another movement component occurs parallel to the slit longitudinal direction given always-constant parallel alignment of the absorber elements. Such a parallelogram-like movement is in particular specified in DE 42 26 861 C2, especially in claim 1.

According to a preferred embodiment of the first variant, the absorber elements can move independent of one another. It is therewith in particular possible to move the absorber elements not only opposite to one another, but rather also concurrently in one and the same direction. For example, a diaphragm readjustment is thereby also possible given a variation of the focus position in the diaphragm rays occurring during the operation (focal spot tracking). This means that the entire slice can also be shifted in the z-direction with a constant slice width. Moreover, a dynamic variation of the collimation width is therewith possible, whereby (for example) an unwanted over-radiation at the beginning and at the end of a spiral scan can be reduced, in that one of the absorber elements is still closed at the beginning of the scan and is only opened at the beginning of the scan with the beginning of the translatory patient bed movement in the direction of the system axis. The same is correspondingly true in reverse for the end of the scan.

The adjustment device for each of the absorber elements comprises a separate adjustment means, whereby the adjustment means are, for example, fashioned for a linear movement of the appertaining absorber element. Via such a linear movement, it is ensured in an advantageous manner that matching sections of the absorber elements "with the same slit width" also still lie opposite one another after a relative movement in the direction of the system axis.

With particular advantage, the adjustment means comprise a (preferably mutual) linear guide as well as, respectively, a drive means [actuator] acting on the absorber elements.

According to a second preferred variant, in the gating device according to the invention the absorber element is fashioned as a preferably one-piece or one-part body in which are introduced a plurality of slits with average slit widths differing from one another, whereupon at least one and preferably all exhibits or, respectively, exhibit a slit width varying in the slit longitudinal direction. For

example, an arithmetic average value of the slit widths differing in the slit longitudinal direction forms the basis as an average slit width.

The slits are aligned with their slit longitudinal direction preferably parallel to one another.

The body is in particular movable as a whole in a direction perpendicular to the slit longitudinal direction, which is especially parallel to the system axis of a computer tomography apparatus equipped with the gating device, for which a drive means and/or a linear guide can be provided.

With regard to a space-saving, compact design, it is particularly of advantage that the body of the absorber element is fashioned flat, in particular plate- or disc-like. Such a plate or disc can also be linearly moved particularly simply.

The object with regard to the apparatus is achieved with regard to the computer tomography apparatus already cited according to the invention, in that the gating device of the computer tomography apparatus is fashioned corresponding to the gating device according to the invention. The slit longitudinal direction thereby preferably stands perpendicular to the system axis or rotation axis.

Advantages and preferred embodiments as well as variants are applicable to the computer tomography apparatus according to the invention in a manner analogous to that for the gating device according to the invention.

The x-ray detector of the computer tomography apparatus is in particular a matrix-like detector array, for example a multi-row detector or a planar detector.

According to a very particular embodiment of the computer tomography apparatus, the slit width $\ell = \ell(\beta)$ varies dependent on the cosine of a fan angle ß, whereby the

fan angle ß is the angle between an eccentric [off-center] ray of the x-ray beam and a central ray.

The variation is in particular described by the following equation:

$$\ell(\beta) = C/\cos\beta + D,$$

whereby C and D are selectable as constants in the production for the appertaining slit. Functional dependencies approximating this equation, for example a series expansion according to the fan angle ß, are also applicable.

The invention is subsequently explained in detail using three exemplary embodiments and by means of Figures 1 through 7 (schematic only in part). Thereby shown are:

Fig. 1 in partially perspective, partially block diagram representation, a CT apparatus comprising a gating device according to the invention,

Fig. 2 a known gating device, whereby the function of the gating device is illustrated in perspective,

Fig. 3 a further known gating device,

Fig. 4 the gating device of the CT apparatus of Figure 1 in a schematic representation according to a first exemplary embodiment,

Fig. 5 the gating device of the CT apparatus of Figure 1 in a schematic representation according to a second exemplary embodiment,

Fig. 6 the gating device of the CT apparatus of Figure 1 in a schematic representation according to a third exemplary embodiment, and

Fig. 7 the gating device of Figures 4 and 5 in a cross-section representation.

A CT apparatus of the 3rd generation is shown in Figure 1 in relevant section [sic]. Its measurement arrangement comprises an x-ray radiator 2 with a gating device 3 positioned in front of it, near the source, and an x-ray detector 5, fashioned as a laminar array of a plurality of rows and columns of detector elements (one of these is designated with 4 in Fig. 1), with an optional beam diaphragm (not explicitly shown) positioned in front of said x-ray detector 5, close to the detector. For reasons of clarity, in Figure 1 only 4 rows of detector elements 4 are shown; however, the x-ray detector 5 can comprise further rows of detector elements 4, optionally also with different widths b.

The x-ray radiator 2 with the gating device 3 on the one side and the x-ray detector 5 with its beam diaphragm on the other side are mounted opposite one another on a rotary frame (gantry) (not explicitly shown), such that a pyramidal (viewed in the z-direction: fan-shaped) x-ray beam emitted by the x-ray radiator 2 in the operation of the CT apparatus 1 and gated by the adjustable gating device 3 (the ray beams of which x-ray beam are designated with 8) impinges on the x-ray detector 5. By means of the gating device 3 and, if applicable, by means of the detector-proximal beam diaphragm, a desired cross-section (more precisely: half-value width) of the x-ray beam is thereby adjusted such that only that region of the x-ray detector 5 is uncovered that should be directly met by the x-ray beam. In the operating mode illustrated in Figure 1, this [sic] are four rows of detector elements that are designated as active rows. If applicable, further existing rows are covered by the detector-proximal beam diaphragm and are therefore not active. The gating device 3 thereby primarily amounts to the importance [sic] of preventing an unnecessary radiation exposure of the examination subject, in particular a patient, in that rays that otherwise do not arrive at the active rows are also kept away from the examination subject or patient.

The rotary frame can be displaced in rotation around a system axis Z by means of a drive device (not shown). The system axis Z runs parallel to the z-axis of a spatial rectangular coordinate system shown in Fig. 1.

The columns of the x-ray detector 5 likewise run in the direction of the z-axis, while the rows (whose width b is measured in the direction of the z-axis and is, for example, 1 mm) run transverse to the system axis Z or, respectively, the z-axis. The x-ray detector 5 is curved or arched around an axis running parallel to the z-axis.

In order to be able to bring the examination subject, for example the patient, into the beam path of the x-ray beam, a bearing device 9 is provided that can be shifted parallel to the system axis Z, thus in the direction of the z-axis, and in fact such that a synchronization exists between the rotation movement of the rotary frame and the translation movement of the bearing device 9 in the sense that the ratio of translation speed to rotation speed is constant, whereby this ratio is adjustable in that a desired value selected for the infeed h of the bearing device 9 per rotation of the rotary frame.

A volume of an examination subject located on the bearing device 9 can thus be examined in the course of a volume scanning [sampling], whereby the volume scanning is effected in the form of a spiral scanning in the sense that, under rotation of the rotary frame and simultaneous translation of the bearing device 9 per rotation of the rotary frame, a plurality of projections is acquired from various projection directions. Given the spiral scanning, the focus F of the x-ray radiator 2 moves on a spiral track S relatively to the bearing device 9. A sequence scan is also possible as an alternative to this spiral scan.

The measurement data, read out in parallel during the spiral scan from the detector elements of each active row of the detector system 5 and corresponding to the

individual projections, are subjected to a digital-analog conversion in a data processing unit 10, serialized and transferred to an image computer 11 which shows the result of an image reconstruction on a display unit 16, for example a video monitor.

The x-ray radiator 2, for example an x-ray tube, is supplied with the necessary voltages and currents by a generator unit 17 (optionally likewise mutually rotating). In order to be able to adjust this to the respectively necessary values, a control unit 18 with keyboard 19 that allows the necessary adjustments is associated with the generator unit 17.

The other operation and control of the CT apparatus 1 also ensues by means of the control unit 18 and the keyboard 19, which is illustrated in that the control unit 18 is connected with the image computer 11.

Among other things, the number of the active rows of detector elements 4 (and therewith the position the gating device 3 and of the optional detector-proximal beam diaphragm) can be adjusted, for which the control unit 18 is connected with adjustment units 20 or, respectively, 21 associated with the gating device 3 and the optional detector-proximal beam diaphragm. Furthermore the rotation time that the rotary frame requires for a complete rotation can be adjusted, which is illustrated in that a drive unit 22 associated with the rotary frame is connected with the control unit 18.

In Figure 2, it is shown which gating results given a known gating device 3A with two separate absorber elements 30A, 31A. Shown is an x-ray beam with edge rays 8A which emanates from a focus F of an x-ray radiator 2A. The x-ray beam comprises a plurality of x-rays. There is a fan angle ß for each ray. The fan angle ß is measured with regard to a central ray 36A that passes through the gating device 3A perpendicular to a center position. The separation of the central ray 36A from the absorber elements 30A, 31A is designated with h_0.

The plane of the gating device 3A is a plane perpendicular to the connecting line from the focus F to the rotation axis Z (see Figure 1). This connecting line coincides in Figure 2 with the central ray 36A.

The shown conventional gating device 3A exhibits the same opening or slit width ℓ for all fan angles ß. The following problem results from this: both the edge rays 8A passing the (in Figure 2) back-side absorber element 30A respectively cover (starting from the focus F) a distance h(ß) from the absorber element 30A that depends on the fan angle ß:

$$H(\beta) = h_0/\cos\beta > h_0 \qquad \text{[Eq. 1]}$$

In contrast to this, the comparable distance h_0 exhibits a lower value given the indicated central ray 36A than given the edge rays 8A. The same is correspondingly true for the edge rays on the opposite side of the slit 32A. The result is that an x-ray beam whose outer contour 34A is not rectangular is gated on the x-ray detector 5A with its individual detector elements 4A in cross-section. In order to fully illuminate all detector elements 4A of the detector row (with its width b) illuminated here, the outer contour 34A must be set such that its width d(ß) at the edge approximately corresponds to the width b of the detector row. As a result of the different distances $h(\beta) \neq h_0$, a larger width d_0 of the outer contour 34A of the x-ray beam then results in the middle of the detector row. The portion of the x-ray beam occurring in this barrel-shaped region (here shown exaggerated, but nevertheless disturbing with regard to the radiation dose) is ultimately not used.

Resulting from the ray set for the gated width d(ß) for an eccentric fan angle ß is

$$d(\beta) = x \cdot \ell / h(\beta) \qquad \text{[Eq. 2]}$$

and, with equation 1:

$$d(\beta) = x \cdot \ell \cdot \cos\beta / h_0 \qquad [Eq. 3]$$

In the equations, x stands for the focus-detector separation. Due to the curvature of the detector 5a (see also Figure 1), x is just as large for an edge ray 8A as for the central ray 36A. h_0 can also be understood as the difference of the distance focus-rotation axis and the distance diaphragm-rotation center and is typically 200 mm.

A further known gating device 3A of a CT apparatus is illustrated in Figure 3 in schematic representation and perspective view. The gating device 3A comprises a curved absorber element 51A in which is formed a slit 32A that can pass the x-rays starting from the focus F of the x-ray radiator 2A. The absorber element 51A is curved in the shape of a circular arc, whereby the middle point of the circular arc lies in the focus F of the x-ray radiator 2A. With regard to the problem shown with equation 1, it should thereby be ensured that the separation, both of the edge rays 8A and of a central ray 36A respectively measured from the focus F to the absorber element 51A, respectively exhibits the same value h. It should thereby be achieved that the x-ray beam gated on the curved x-ray detector 5A exhibits in cross-section a rectangular outer contour 34A whose constant width d can be adapted to the width b of one or more detector rows.

A gating device 3 according to the invention, as it is assembled in the CT apparatus 1 of Figure 1 with the curved detector 5, is reproduced in Figure 4 in a schematic representation according to a first exemplary embodiment. The geometry – in particular also with regard to the focus-detector distance x – is largely identical with that of Figure 2, for reasons of which the designations already used in this Figure are referenced with regard to the designations used.

The absorber elements 30, 31 (produced from heavy metal, for example from tungsten or/and from tantalum) can move or travel independent of one another, in particular also counter or together with one another, which is indicated by

corresponding double arrows 40, 41 in Figure 4. The absorber elements 30, 31 are shaped, i.e. exhibit on the slit-side a curved outer contour, such that the slit 32 exhibits a slit width ℓ varying in the slit longitudinal direction 42 and increasing towards the slit ends. The absorber elements 30, 31 are correspondingly contoured to their slit-demarcating edges 43 or, respectively, 44.

The invention begins from the consideration that the problem resulting from equation 1 is to be solved starting from equation 3, in that the gated width d(ß) is set as a constant: d(ß) = d, and then equation 3 is solved according to a slit width $\ell = \ell(ß)$ assumed to be varying with the fan angle ß:

$$\ell\,(ß) = d \cdot h_0/(x \cdot \cos ß) \qquad \text{[Eq. 4]}$$

The slit width $\ell = \ell(ß)$ this generally varies according to

$$\ell\,(ß) = C/\cos ß + D = C \cdot \sec ß + D \qquad \text{[Eq. 5]}$$

with the fan angle ß, whereby C and D apply for the appertaining slit 32 as constants independent of the fan angle ß. The slit-demarcating edges 43 or, respectively, 44 are correspondingly rounded.

For not-too-large angles, a curve progression approximated according to a series expansion is also applicable:

$$\ell\,(ß) = E + F \cdot ß^2 \qquad \text{[Eq. 6]}$$

whereby E and F are selectable as constants for the appertaining slit 32.

A gating device 3 according to the invention according to a second exemplary embodiment is shown in Figure 5, as it can be installed in the CT apparatus 1 of Figure 1. In contrast to the exemplary embodiment of Figure 4, the slit-

demarcating edges 43A or, respectively, 44A of the absorber elements 30, 31 are not curved, but rather composed of a plurality of straight sections. The absorber elements 30, 31 thus exhibit an outer contour polygonally approximating a curve. In a middle first region 45 of approximately 50 mm in length, the slit width ℓ is constant. In each further region 46, 47 (length approximately 75 mm) adjacent on both sides of the first region 45, the slit width ℓ increases linearly towards the ends. The increase $\Delta\ell$ of the slit width ℓ is, for example, 0.4 mm.

The embodiment of the gating device 3 according to Figure 5 is in particular of advantage in the case of an adjustment device that generates a parallelogram-like relative movement between the absorber elements 30, 31 to modify the diaphragm opening. Namely, it has been shown that the movement also occurring (among other things) in the x-direction in the parallelogram-like movement, which movement in the x-direction leads to a displacement of the centers of the absorber elements 30, 31, has particularly little effect given a gating device 3 executed with three regions 45, 46, 47, in particular in that errors with regard to this are corrected to the largest possible extent via introduction of calibration implemented at the beginning of a measurement.

A gating device 3 according to the invention according to a third exemplary embodiment is shown in Figure 6, as it can likewise be installed into the CT apparatus 1 of Figure 1. Only a single, one-piece or one-part, plate- or disc-like absorber element 51 is hereby present, in which have been introduced a plurality of slits 52, 53, 54, 55, 56, 57 with average slit widths differing from one another. The slits 52, 53, 54, 55, 56, 57 are aligned parallel in the slit longitudinal direction 42 and exhibit a slit width ℓ varying in the longitudinal direction 42. The length L of the absorber element 51, measured in the z-direction, is approximately 70 mm; its width B, measured in the x-direction, approximately 200 mm. For better representation of he contoured openings, the absorber element 51 is thus not shown with a uniform scale in Figure 6. The absorber element 51 can be linearly shifted in the z-direction, thus perpendicular to the slit longitudinal direction 42, which is

indicated by the double arrow 59. Corresponding adjustment means comprising a drive means 60 and a guide element 61 are only schematically indicated.

The gating device 3 of Figure 4 and 5 is explained again in Figure 7 in a cross-section representation in the z-direction. Therein it is in particular visible that the absorber elements 30, 31 are slightly displaced relative to one another in the height direction y, essentially corresponding to the direction of the radiated x-ray beam, in order to achieve an overlapping of the absorber elements 30, 31 necessary for a complete closure of the gating device 3.

Moreover, in Figure 7 it is visible that a first drive means 63 can be provided as an adjustment device 61 for the absorber element 30 and a separate drive means 67 can be provided for the other absorber element 31, which drive means act on the absorber elements 30, 31 movable along the common linear guide 65 via toothed belts and/or gears. The adjustment device 61 is connected with the control unit 18. The adjustment device 61 can alternatively drive both absorber elements 30, 31 with a common motor.